Ω_b^-

DØ Collaboration

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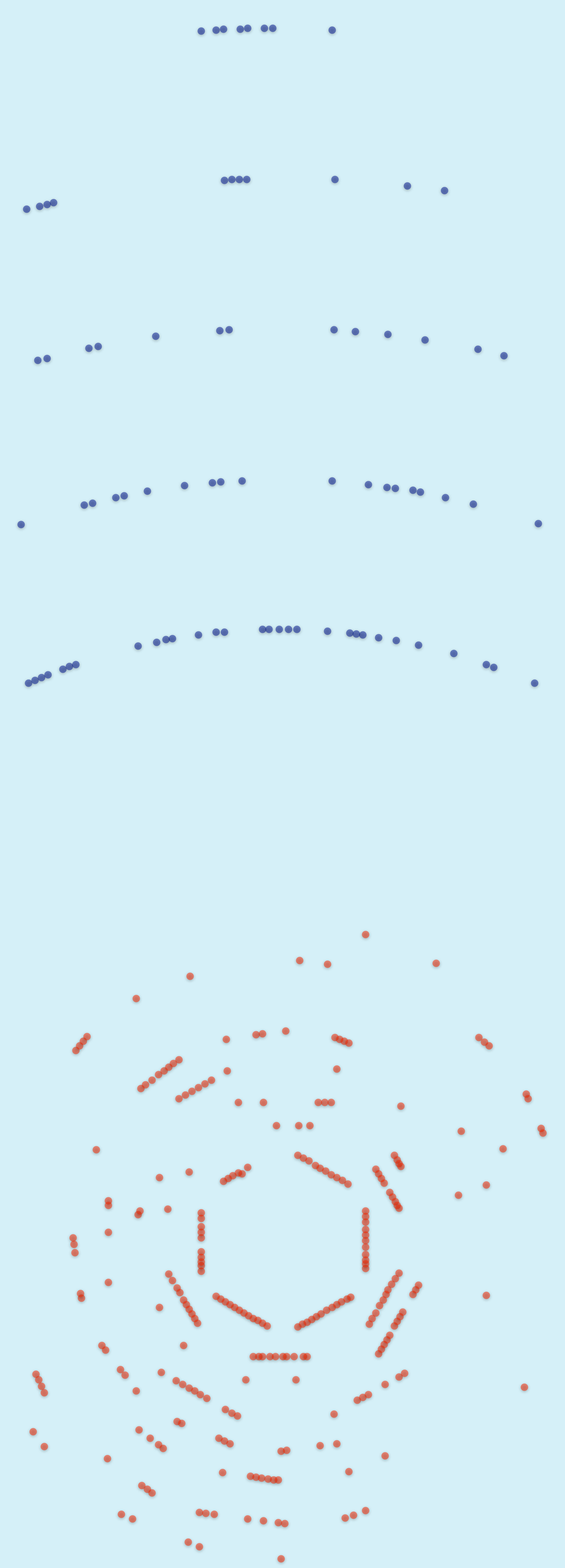
Observation of the doubly strange b–baryon Ω_b^-

On behalf of the DØ Collaboration • Jesus Orduna • CINVESTAV IPN, Mexico City

Collisions



Connect the dots

Every collision at the Fermilab Tevatron Collider gives High Energy Physicists a set of dots; hits of particles as they interact with the different detector subsystems. The job is then to use their skills to extract the physics out of the dots.

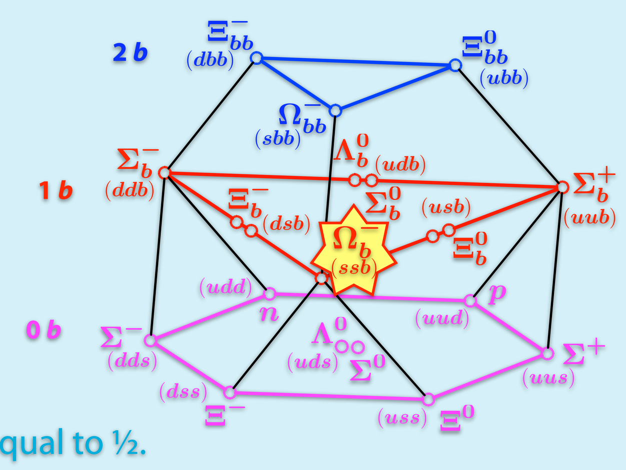
The DØ Collaboration is a worldwide group of scientists. One of their activities is to study those collisions in order to achieve a better understanding of the fundamental constituents of matter and the interactions between them.

I. b–Baryons with $J = ½$

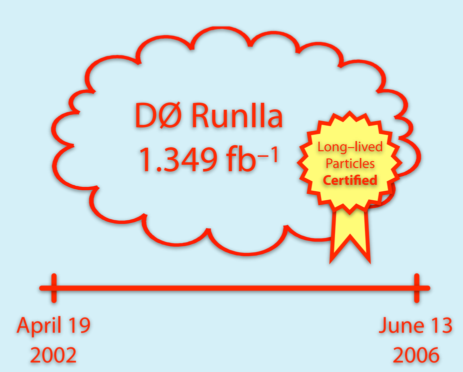
The family of particles made of three quarks is known as baryons.

b–Baryons are those containing at least one b quark.

In this case we look at the ones having a total angular momentum J equal to ½.



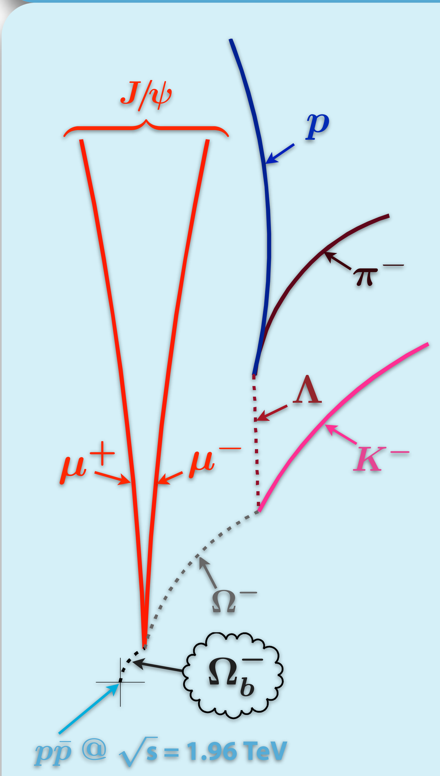
II. Data



This analysis was performed with 1.349 fb⁻¹ of data collected in $p\bar{p}$ collisions at $\sqrt{s}=1.96$ TeV with the DØ detector [1], at the Fermilab Tevatron Collider.

These data was reprocessed with an extended tracking reconstruction code to increase the identification efficiency of long–lived particles such as the Ω^- (sss).

III. Decay & J/ψ selection



We look for the following Ω_b^- decay mode:

$$\Omega_b^- \to J/\psi\ \Omega^-$$

with

$$J/\psi \to \mu^+\mu^-,\ \ \Omega^- \to \Lambda K^-$$

and

$$\Lambda \to p\pi^-.$$

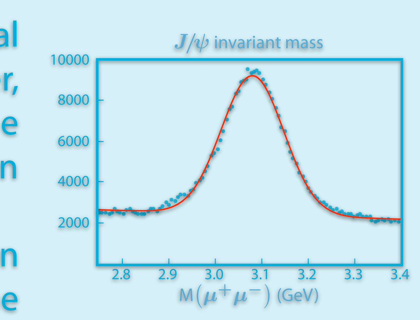
Its topology is depicted on this figure.

We took some initial information from both, theory and the accumulated experience from the analysis which led to the first observation of the Ξ_b^- (dsb), in the summer of 2007 by DØ [2], which have a similar decay chain.

J/ψ

With the information from the central tracking system and the calorimeter, we select two opposite–charge muons coming from a common vertex.

The reconstructed $p\bar{p}$ interaction point is the one we take as the production vertex for the Ω_b^-.

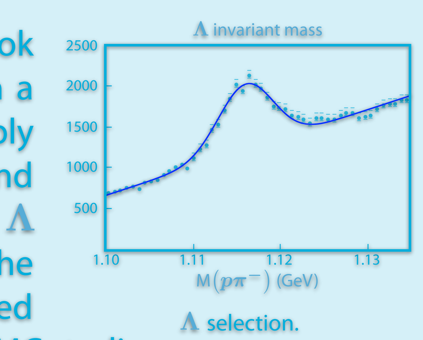


J/ψ selection.

IV. Λ optimization

Λ

Once we have selected J/ψ's, we look for two opposite–charge tracks with a common vertex to form a Λ. We apply some restrictions to these tracks and the vertex in order to reduce the Λ background as much as we can. The track with the higher p_T, is assumed to be the proton as we confirm from MC studies.



Λ selection.

$\Lambda K^\pm$

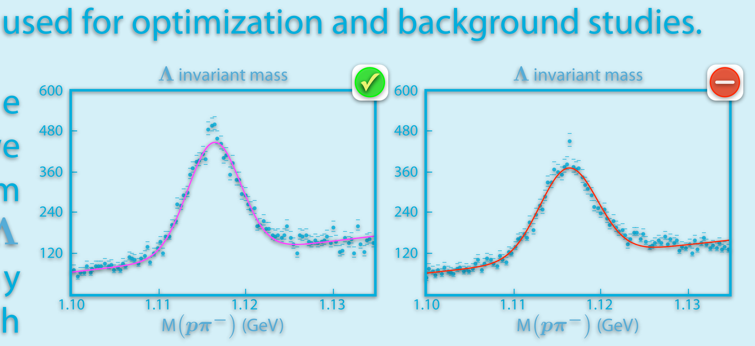
Resulting Λ's are combined with an extra track, which is assumed to be a K.

Depending on the charge of the K, we define two separate sets:

Correct Sign ΛK^-: used to form Ω^- candidates.

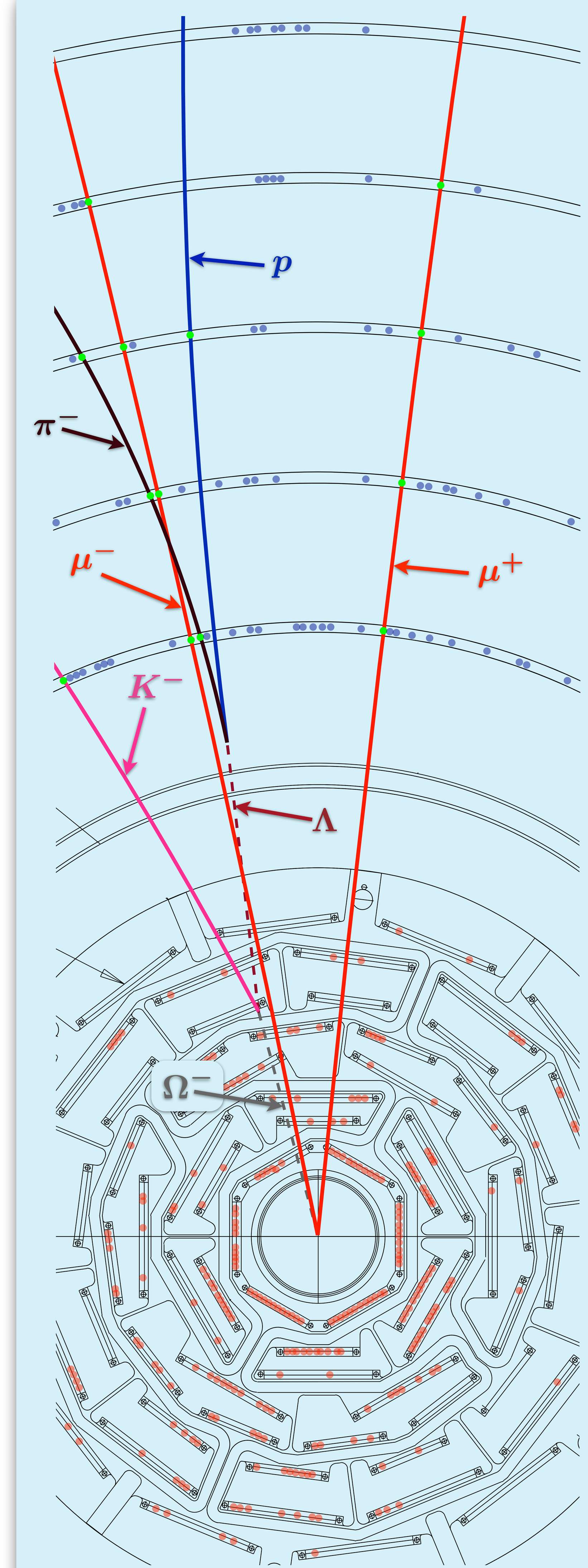
Wrong Sign ΛK^+: used for optimization and background studies.

Using the wrong–sing we find an optimum cut in the Λ proper decay length significance that allows us to clean the signal without the direct use of the right–sign candidates.



Optimized Λ selection.

Observed Particle



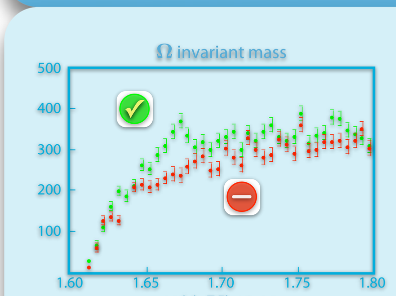
Run 203929. Event 22881065.
$M(\Omega_b^-) = 6.158$ GeV

The figure shows one of the events we found consistent where we have identified clearly each one of the final particles as well as the reconstructed intermediate states.

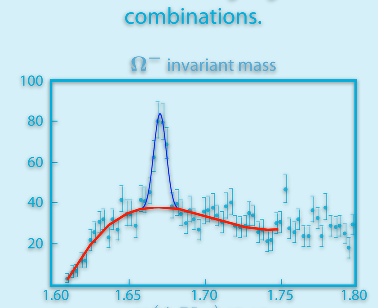
The cross section of the central tracking has been superimposed.

The red points correspond to the Silicon Microstrip Tracker (SMT), in blue those belonging to the Central Fiber Tracker (CFT) and in green we have identified the hits used to reconstruct the specific tracks.

V. Ω^-



Correct/Wrong–sign combinations.



Ω^- with BDT cut.

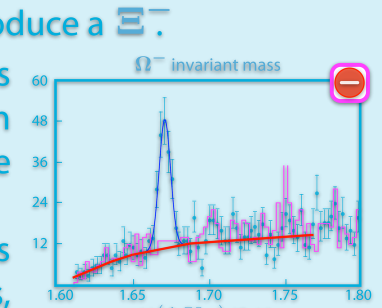
We use multivariate analysis techniques [3] to clean the ΛK^- combination.

A BDT classifier with 20 variables takes into account the most important characteristics of the final particles to improve the quality of the Ω^- signal.

To train the BDT, we use $\Omega^- \to \Lambda\ K^-$ MC events from $\Omega_b^- \to J/\psi\ \Omega^-$ decays as signal and wrong–sign combinations as background.

Due to their similar decay topologies, we investigate the possibility of assign a K mass to an actual π track –which would give a Ξ^- instead of Ω^-,– and remove those events which consistently produce a Ξ^-.

After removing possible Ξ^- events, is evident that only the correct–sign combination shows an excess in the number of Ω^- candidates.



Final optimization of Ω^-.
Wrong–sign superimposed in magenta.

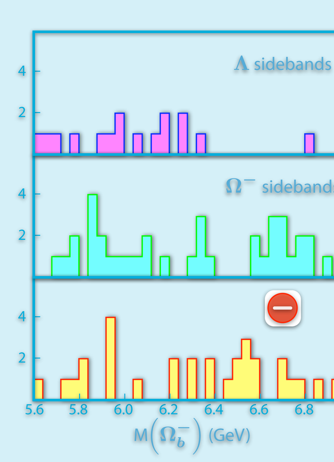
As in the Ξ_b^- analysis [2], the mass definition for the resulting candidates, combines constructed and reported[3] masses for the J/ψ, Ω^- and their combination. Applied to MC events, we reproduce the input mass used at generation level. We also see an improvement in the MC mass resolution. The mass is:

$$\mathrm{M} = \mathrm{M}(J/\psi\ \Omega^-) - \mathrm{M}(J/\psi) - \mathrm{M}(\Omega^-) + \hat{\mathrm{M}}(J/\psi) + \hat{\mathrm{M}}(\Omega^-)$$

M's are reconstructed while $\hat{\mathrm{M}}$'s are reported in [3].

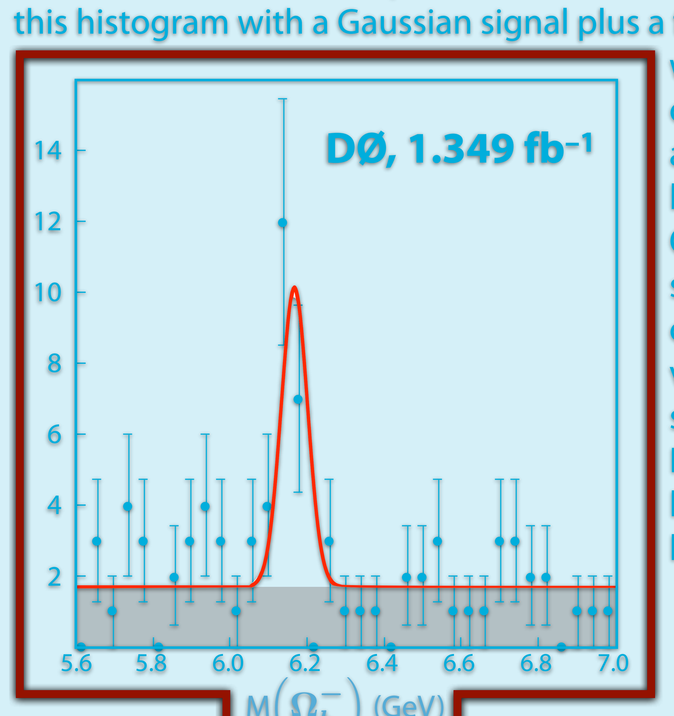
VI. Final Combination

The final combination with all selection criteria, was made first taking various samples where we don't expect to find any signal like wrong–sign, sidebands and MC from b–decays with similar topologies; to test for an *"artificial production"* due to the method. As expected, we don't see any signal where it is not supposed to be.



Erroneous combinations.

In the correct combination, we see an excess of events. We report the fit to this histogram with a Gaussian signal plus a flat background, but we also tried various other hypothesis about signal and background shapes.



Observed signal.

Our main source of systematic error comes from the variation in the selection criteria.

Finally, we use the logarithmic likelihood ratio:

$$\sqrt{2 \ln \frac{\mathcal{L}_{S+B}}{\mathcal{L}_B}}$$

to determine the significance of the signal.

VII. Result [5]

Using 1.349 fb⁻¹ of data collected with the DØ detector from $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, at the Fermilab Tevatron Collider, we find 17.8 ± 4.9 (stat) $\pm$ 0.8 (syst) Ω_b^- events following the decay chain $\Omega_b^- \to J/\psi\ (\mu^+\mu^-)\ \ \Omega^-\ (\Lambda\ [p\pi^-]\ K^-)$.

We obtain a mass of 6.165 ± 0.010 (stat) $\pm$ 0.013 (syst) GeV with a significance of $5.4\ \sigma$.

The probability of the signal coming from a fluctuation in the background is 6.7×10^{-8}.

All the hypothesis we have used to model the signal and background give a significance greater than $5.0\ \sigma$.

This analysis is the first experimental evidence of this decay.

References

[1] V. M. Abazov *et al.* (DØ Collaboration), Nucl. Instrum. Meth. A **565**, 463 (2006).
[2] V. M. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **99**, 052001 (2007).
[3] A. Höcker *et al.*, arXiv:physics/0703039.
[4] C. Amsler *et al.* (Particle Data Group), Phys. Lett. **B667**, 1 (2008).
[5] V. M. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **101**, 232002 (2008).